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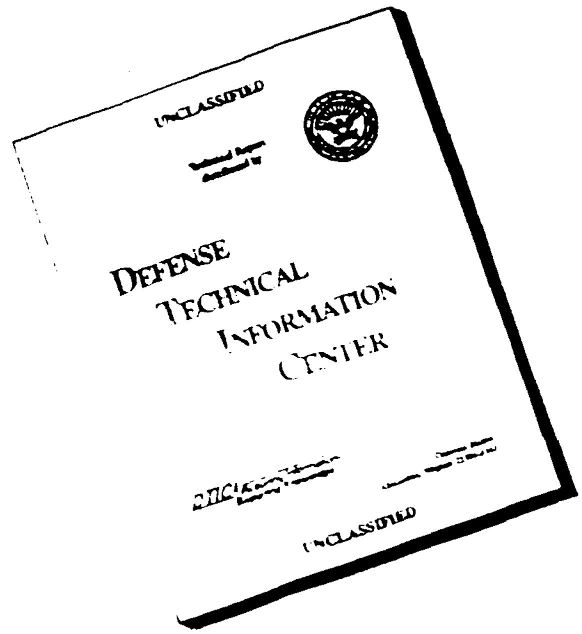

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As the Navy's lead laboratory in Mapping, Charting and Geodesy, the Naval Research Laboratory (NRL) was tasked by the Defense Mapping Agency (DMA) to develop a draft product specification for a Digital Nautical Chart (DNC) database. This paper describes the DNC database design, intended use, and prototype production schedule as of mid 1992.

The DNC database is intended to be used in the Navigation Sensor System Interface (NAVSSI) aboard U.S. Navy ships. The NAVSSI project is a new system being designed with two primary objectives; processing/distribution of navigation data and the display/operation of electronic charts. NAVSSI will be the Navy's Electronic Chart Display and Information System (ECDIS). The goal of NAVSSI is to replace paper charts as a legal means of ownship navigation plotting (1).

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DIGITAL NAUTICAL CHART

James A. Hammack[1] and Mel Wagner[2]

INTRODUCTION

the Navy's lead laboratory in Mapping, Charting and Geodesy, the Naval Research Laboratory (NRL) was tasked by the Defense Mapping Agency (DMA) to develop a draft product specification for a Digital Nautical Chart (DNC) database. This paper describes the DNC database design, intended use, and prototype production schedule as of mid 1992.

The DNC database is intended to be used in the Navigation Sensor System Interface (NAVSSI) aboard U.S. Navy ships. The NAVSSI project is a new system being designed with two primary objectives; processing/distribution of navigation data and the display/operation of electronic charts. NAVSSI will be the Navy's Electronic Chart Display and Information System (ECDIS). The goal of NAVSSI is to replace paper charts as a legal means of ownship navigation plotting (1).

The DNC will be a seamless, vector database distributed on CD-ROM. DNC will eventually provide world-wide coverage at every scale now used for marine navigation. The database will include all features currently shown on National Ocean Service (NOS) and DMA charts.

The DNC is implemented in DMA's Vector Product Format (VPF). VPF is an evolving standard, intended to be a general, user-oriented data format for representing large spatially referenced (geographic) databases. VPF is intended for the production of nautical, aeronautical, and topographic charts and maps to support all agencies of the Department of Defense.

2 VPF OVERVIEW

Vector Product Format is intended to be a standard format for DMA's distribution of vector data. VPF uses a geo-relational data model to provide an organizational structure for any digital geographic database in vector format. VPF establishes a standard data model and organization, providing a consistent interface to data content. The DNC product specification determines the precise data contents of feature tables and their relationships (2).

A VPF database is composed of tables and directories that form a layered model. A VPF table is the organizational structure for all data content in VPF and consists of the following parts: a table header, which contains metadata about the table and the column definitions; the table contents, which contain the actual rows that make up the table; and a row id. Figure 1 depicts a schema that defines the principal structure of any table in VPF (3).

Figure 2 depicts the relationships between databases, libraries, coverages, feature classes and primitives in VPF. A collection of libraries makes up the database while a collection of thematic coverages makes up each library. Databases and libraries are used primarily to help organize data access, whereas coverages are used to define the relationships between features. Topology is incorporated at the coverage level to define spatial relationships between features. Since topology is present only at the coverage level, this presents difficulties in determining thematic coverage contents for the DNC. Geometric and cartographic primitives are at the lowest level. These primitives define the spatial aspects of entities. Also at this level are feature classes, which contain thematic information that helps apply meaning to the primitives. Both feature classes and primitives make up the thematic coverages.

A database is a collection of related libraries plus additional tables which define data that is common to all of the libraries.

A library is a collection of coverages which share a single coordinate system and scale, have a common thematic definition, and are contained within a specified spatial extent. All of the tables and coverages making up the library are contained within a single directory.

At the database and library levels, various tables are required to define the database geographic extent, sources, accuracy, security, etc. At the thematic coverage level feature tables, value description tables, and primitive tables define features and attributes along with their spatial relationships.

A coverage is a set of feature classes (consisting of primitive and attribute tables) whose primitives interconnect according to coverage topology. A coverage is analogous to a single map sheet in conventional cartography. At this level, features are represented by a set of one or more primitives plus a row of attribute data. Every feature will have one primary row in a feature table that uniquely identifies it. Value description tables (VDT) relate the possible numeric or character values contained in the feature table to possible attributes for the features.

VPF defines three geometric primitive types; faces, edges, and nodes. The primitive tables contain the actual latitude and longitude values of the faces, edges, points or text comprising the feature. Index tables are used to decrease access times for variable length files.

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3 DNC IMPLEMENTATION

The DNC database is implemented in VPF and will be distributed on CD-ROM. The DNC is based on the feature content of the paper Harbor, Approach and Coastal charts produced by DMA and uses the Feature and Attribute Coding Catalog (FACC) to define features, attributes, and attribute values. FACC is a Digital Geographic Information Exchange Standard (DIGEST) coding convention and will be used by DMA in production of various digital charts. Figure 3 shows the VPF structure levels and DNC implementation.

The database directory level contains the database header table and the library attribute tables. The database header table contains the database name, originator, security classification and other information concerning the database. The library attribute tables contain the library names and geographic extent of the libraries.

The DNC database is divided into libraries based on source chart scale. Since traditional paper nautical charts are not produced in standard sizes or scales, the DNC groups paper chart sizes into four scale bands and uses an equal-area tiling scheme (see Figure 4). The tile sizes listed in Figure 4 are preliminary, and are subject to change. The lower left (southwest) corner of each tile is identified using the World Geographic Reference System (GEOREF). This system divides the earth into quadrangles or tiles, the sides of which are specific arc lengths of longitude and latitude. The GEOREF identifier is used as the filename in the appropriate library of the database.

The library directory level includes a library header table, a coverage attribute table and a geographic reference table. The library header table contains information identifying the contents, extent, projection, units, security source, and data quality of the library. The coverage attribute table contains an ID, coverage name, description, and topological level for each coverage within the library. The geographic reference table includes four subrecords that define the geographic parameters of the library. These subrecords are: geographic parameters, projections, registration points, and diagnostic points.

In addition to the these libraries, the DNC will include a BROWSE library containing original paper chart boundaries, data quality information, coastline, major ports and CD-ROM coverage information.

The DNC is divided into 14 thematic coverages. These coverages are shown in figure 5. (Coverage names are subject to change).

Within each coverage are feature tables for each feature class (area, line, point and text) and corresponding primitive tables. A sample line feature table is shown in figure 6. This table contains FACS codes for each feature within the coverage, related feature attributes, and a key into the associated primitive table. Figure 7 shows an integer value description table which relates integer values found in the feature table to actual attribute values. A sample edge primitive table for line features is shown in figure 8.

4 UPDATING THE DNC

A primary concern in the production of any digital nautical chart is the management and application of chart updates. Several methods for updating and correcting the DNC have been studied by the Defense Mapping Agency (4).

The three primary categories of chart updating methods are: 1) interactive entry of updates, 2) semi-automatic entry of updates, and 3) automatic entry of updates.

Interactive entry of updates is probably the least complex of the three methods, and also the least elegant. In this method, the present method of distribution of chart update information by electronic and paper means would continue. Each system developer using the DNC would then be responsible for developing the software required to interactively update the DNC on that particular system. Each user would then update the DNC in a manner similar to that in use now for paper charts.

Semi-automatic entry of chart update information involves the distribution of correction data via modem, floppy disk, etc. The data is then entered into the system and displayed as overlay information, readily distinguishable from the original data. The original data is not altered. This method is more complex in that it requires properly structured data from the Hydrographic Office.

The third method of chart updating, the automatic method, is the most complex. As in the previous method, chart updates are distributed in the proper structure via modem, floppy disk, etc. However, the chart corrections are integrated with the original data and are indistinguishable from the original data when displayed.

In both the semi-automatic and automatic methods the update data may be organized around either feature types (thematic layers) or areas (tiles). If the updates are distributed as feature updates, the system software must be capable of adding, modifying and deleting individual features within a thematic coverage. This requires complex software capable of restructuring multiple VPF tables. If the updates are distributed as tile updates, then an entire cell is replaced with a corrected cell. This method requires much less sophisticated system software, in that only metadata tables must be modified. All tables specific to the updated tile are replaced.

A plan for distribution of DNC updates which supports either the semi-automatic or automatic methods has been proposed by DMA. In this approach, two types of coverages are defined; a static coverage and a dynamic coverage. Since 90% or more of current corrective information applies to navigational aids, area limits, and obstructions, this method would specify these thematic coverages to be "dynamic." All other coverages would be designated "static." Static coverages would not be updated weekly, but all information for the dynamic coverages would be updated on a weekly basis. An additional "New Construction" dynamic thematic layer would be added to handle the case where a change is required to a static thematic coverage. This weekly update would include all dynamic coverages world-wide, and would be distributed in VPF on one or two CD-ROMs by the Defense Mapping Agency.

The Naval Research Laboratory is now investigating the optimum method for structuring static and dynamic coverages, and determining possible product specification and VPF standard modifications necessary to support this method for updating the DNC. However, no final decision has yet been made regarding an DNC updating strategy.

5 DNC PROTOTYPE PRODUCTION

The Environmental Systems Research Institute, Inc., (ESRI) in Redlands, California, is producing the DNC prototype for DMA. Several prototypes are planned.

Prototype 1A was produced in late November 1991. It contains two 5' by 5' subsets extracted from data that has been digitized by ESRI for DMA's Digital Chart of the World (DCW) Prototypes 2 and 3. These data were converted to VPF and distributed on floppy disk. Prototype 1A uses the DCW attribute codes, however, rather than the DNC FACS codes.

Prototype 1B was produced in late January 1992. It is structured in VPF and contains the full data sets digitized for DCW Prototypes 2 and 3. Prototype 1B utilizes FACS codes for attribute definition and is distributed on magnetic tape.

Prototype 2 was produced in Spring, 1992. It contains six charts of the Norfolk area; one at the Coastal scale, two at the Approach scale, and three at the Harbor scale. Prototype 2 conforms to the DNC product specification and has been distributed by DMA on CD-ROM.

Prototype 3 is expected to be released in late 1992. This prototype will incorporate changes in thematic coverage content and other modifications intended to improve performance of the DNC.

A fourth prototype intended to test DNC updating strategies is expected to be produced in 1993.

The Naval Sea Combat Systems Engineering Station plans to evaluate the prototype DNC database in the NAVSSI system on board an aircraft carrier in the late summer of 1993.

6 CONCLUSION

The Digital Nautical Chart will provide the U.S. Navy with a standard vector database for marine navigation, mission planning, and tactical and strategic operations. Several issues remain concerning DNC, including the determination of thematic coverages, storage and representation of cartographic text and marginalia, and chart updates. However, with the production of several DNC prototypes and the deployment of the Navigation Sensor System Interface by mid-1992, the Navy will be well on the way to fielding an effective ECDIS.

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2. Environmental Systems Research Institute: A Description of the Vector Product Format. Redlands, CA, July, 1990.

3. Defense Mapping Agency Systems Center: Final Military Standard - Vector Product Format. Washington, DC, April, 1992.

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Figure 1. <u>VPF Table Structure</u>

Table Header	
Metadata and column definitions: a. Table Description b. Narrative File Name (optional) c. Column Definitions: column name column text description field type key type value description table name (optional)	
ID	**Table Contents**
Indicates the starting position of each row.	Data matching the column definitions.

Figure 2. <u>VPF Layers</u>

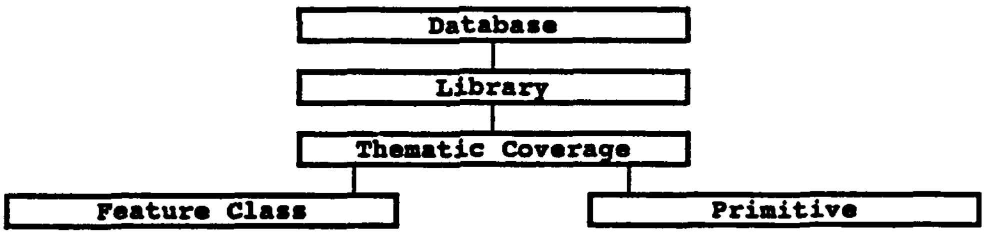

Figure 3. <u>VPF structure levels and DNC implementation</u>

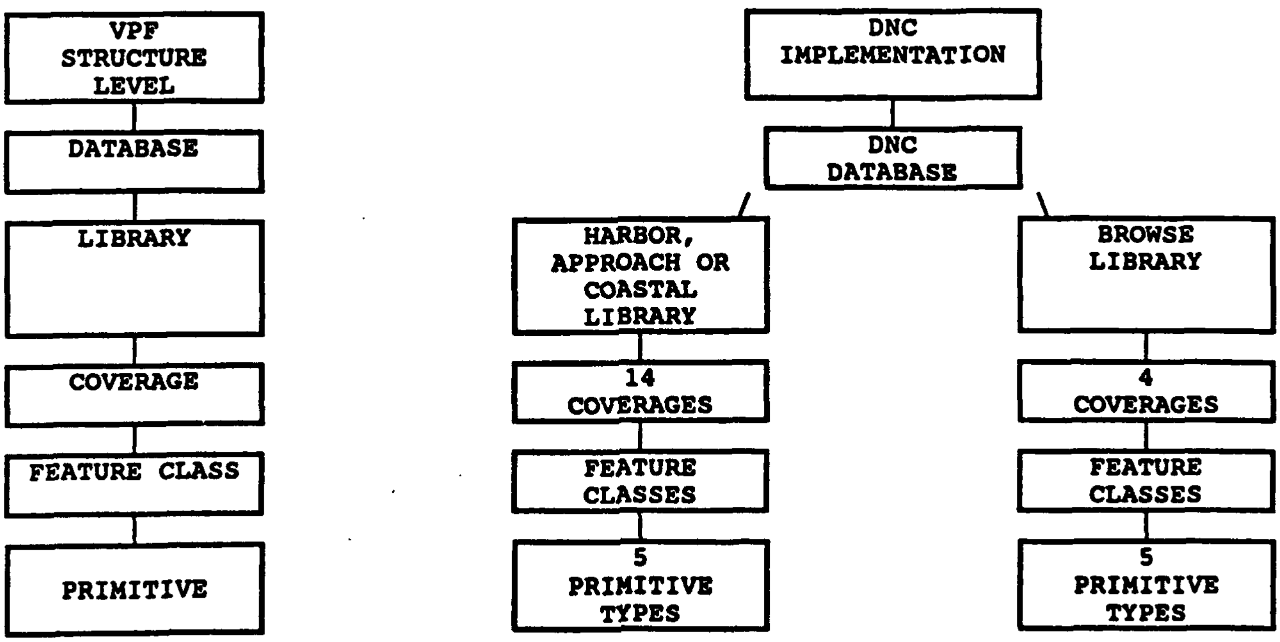

Figure 4. DNC libraries and tile sizes

ID	LIBRARY (chart type)	TILE SIZE	CHART SCALES
A	GENERAL	2.5°	< 1:500,001
B	COASTAL	45'	1:75,000 to 1:500,000
C	APPROACH	7.5'	1:25,000 to 1:100,000
D	HARBOR	7.5'	1:10,000 to 1:50,000

Figure 5. DNC thematic coverages

COVERAGE NAME	DESCRIPTION
cultural landmarks	man-made features on land of interest to marine navigation
earth cover	shoreline, foreshore, open water, etc.
inland water	inland shoreline, lakes, ponds, etc.
land cover	vegetation, snow, ice, etc.
relief	elevations on land
port facilities	berths, piers, etc.
obstructions	rocks, wrecks, etc.
aids to navigation	buoys, lights, etc.
hydrographic	depths, bottom characteristics, etc.
environment	tides, currents, magnetic variation, etc.
general info limits	Colregs demarcation, custom boundary, etc.
caution limits	Work in Progress area, etc.
avoidance limits	prohibited area, restricted area, etc.
navigation limits	channel limits, traffic separation zone, etc.

Figure 6. Partial hydrography line feature table.

```
{Header length};\
HYDLINE.LFT, Hydrography Line Feature Table;-;\
ID=I,1,P,Row ID,-,:\
F_CODE=T,5,N,FACS Code,CHAR.VDT,:\
ACC=I,1,N,Accuracy Category,INT.VDT,;
CRV=I,1,N,Depth Curve or Contour Value,INT.VDT,;
UNI=I,1,N,Units Category,INT.VDT,;
VDC=I,1,N,Vertical Datum Category,INT.VDT,;
VDR=I,1,N,Vertical Datum Record,INT.VDT,;
```

1	2E010	1	10	1	1	1
2	2E010	1	10	1	1	1
3	2E010	1	20	2	1	1
4	2E010	1	20	2	1	1
.	.	.	.	.	.	.

Figure 7. Partial hydrography integer value description table

```
{Header length};\
INT.VDT, Hydrography Integer Value Description Table;-;\
ID=I,1,N,Row ID,-,:\
TABLE=T,12,F,Feature Class Table Name,-,:\
ATTRIBUTE=T,10,F,Attribute Name,-,:\
VALUE=T,5,F,Attribute Value,-,:\
DESCRIPTION=T,50,F,Attribute Value Description,-,;
```

1	HYDLINE.LFT	ACC	001	Accurate
2	HYDLINE.LFT	ACC	002	Approximate
3	HYDLINE.LFT	ACC	003	Doubtful
4	HYDLINE.LFT	EXS	001	Definite
5	HYDLINE.LFT	EXS	002	Doubtful
6	HYDLINE.LFT	EXS	003	Reported
7	HYDLINE.LFT	HDI	009	Depth Known by Other Than Wire
.	.	.	.	.

Figure 8. Schema for edge primitive table.

Column name	Column name description
ID	The row id primary key
*.LFT ID	Line feature table id
START_NODE	Start node foreign key to entity node table
END_NODE	End node foreign key to entity node table
RIGHT_FACE	Right face foreign key to face primitive table
LEFT_FACE	Left face foreign key to face primitive table
RIGHT_EDGE	Right edge foreign key to following edge
LEFT_EDGE	Left edge foreign key to following edge
NEXT_EDGE	Next edge in a line network, foreign key to edge primitive
COORDINATES	Edge coordinates